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(71) Applicants ITT Industries Inc, (USA—Delaware), 320 Park Avenue, New York 10022, State of New York, United States of America
(72) Inventor Brett Munn Austin
(74) Agent and/or Address for Service P. G. Ruffhead, ITT Patent Department UK, Maidstone Road, Foots Cray, Sidcup DA14 5HT

(54) **Manipulator apparatus**

(57) Manipulator apparatus comprises a plurality of movable arm sections (14, 16, 18, 20) connected in series by remotely-controllable pivoting mechanisms (26). Each pivoting mechanism is self-contained except for means for transmitting electrical or fluid power, but not mechanical motion, thereto. As shown, each pivoting mechanism is operable to pivot a respective arm section about a longitudinal axis and an axis transverse to the longitudinal axis.

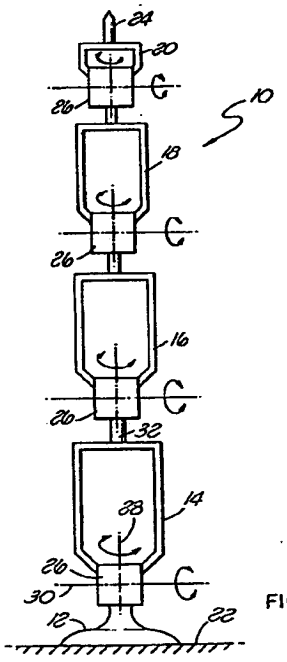

FIG. 1

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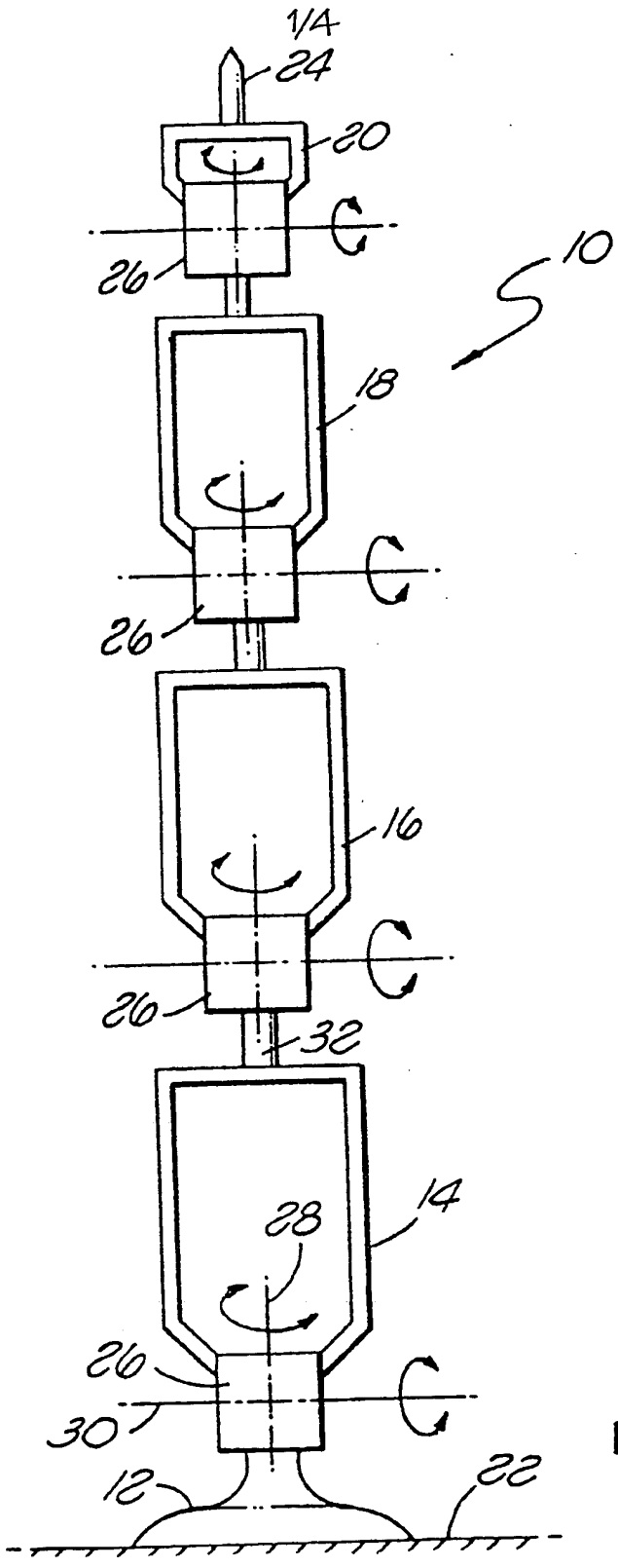

FIG. 1

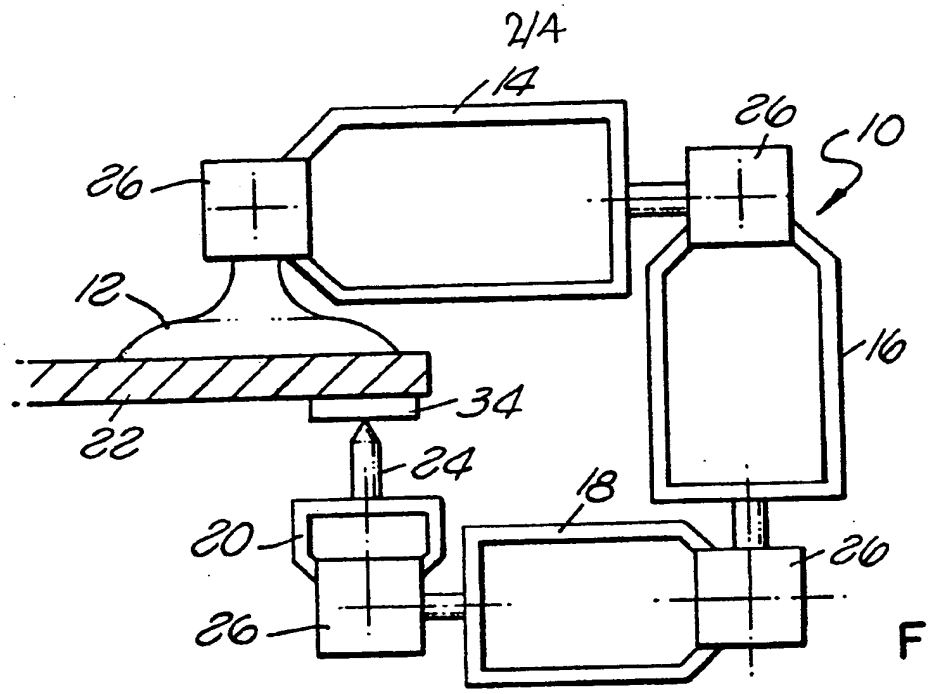

FIG. 2

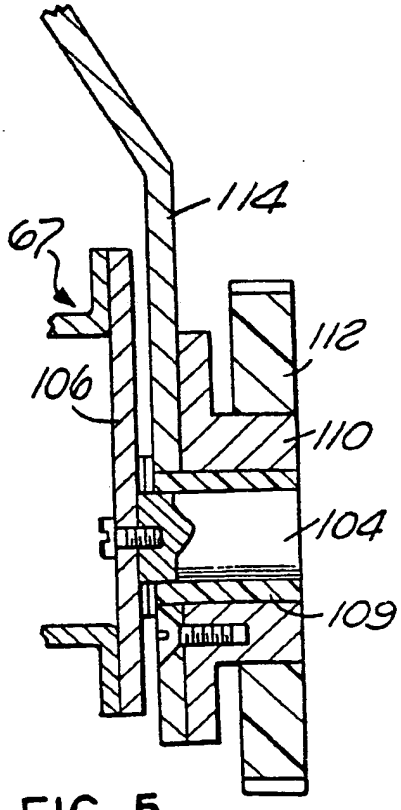

FIG. 5

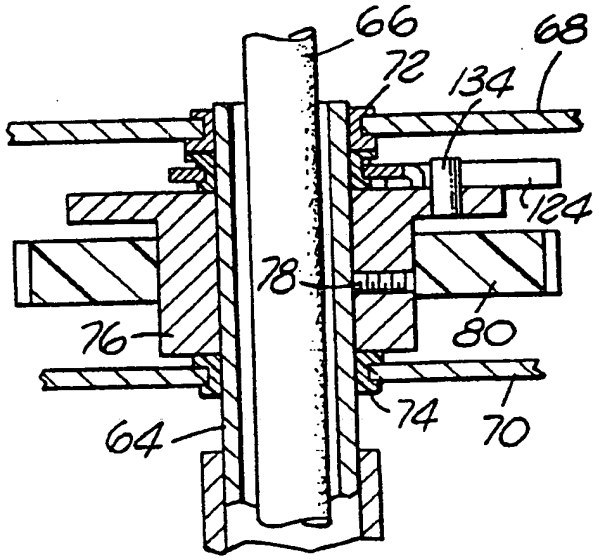

FIG. 4

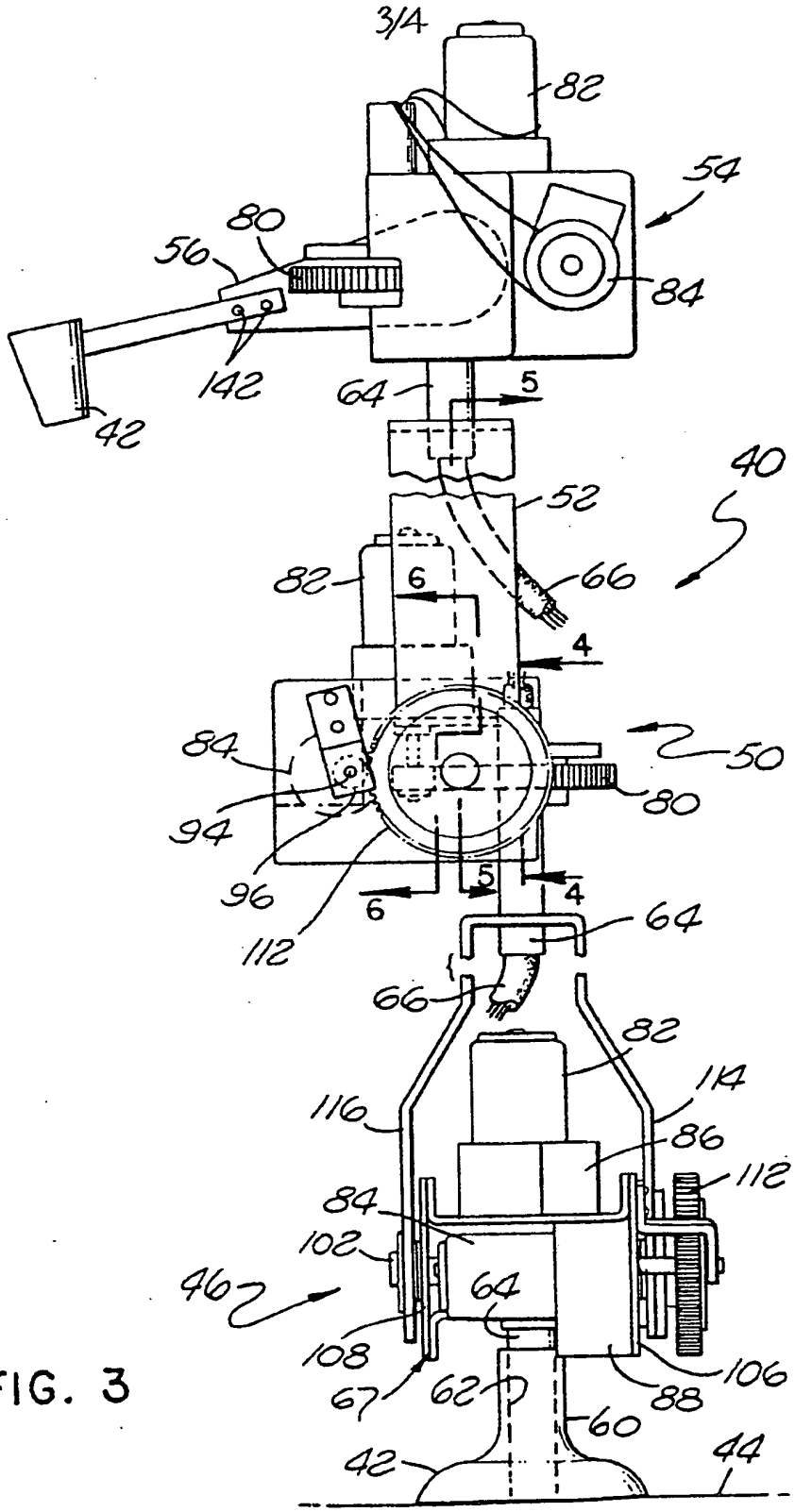
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FIG. 3

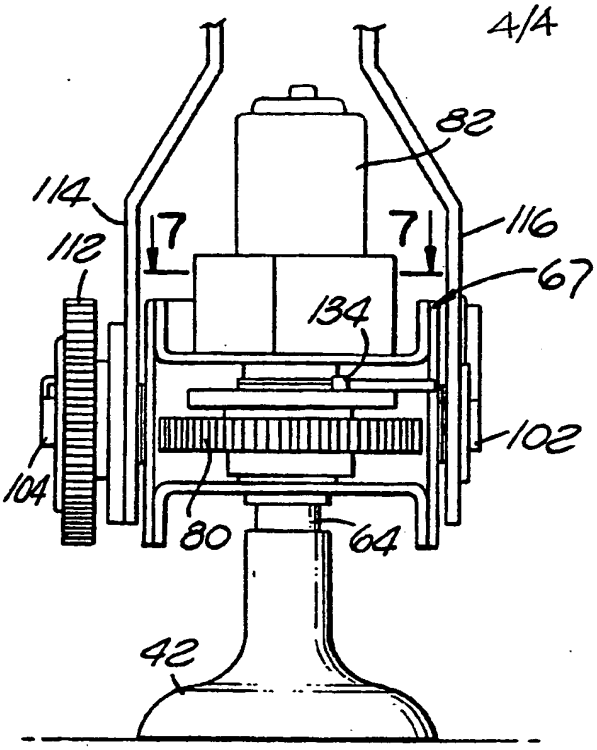


FIG. 5A

FIG. 6

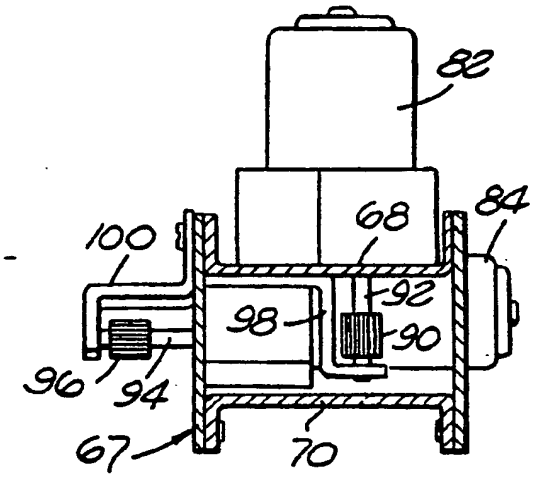
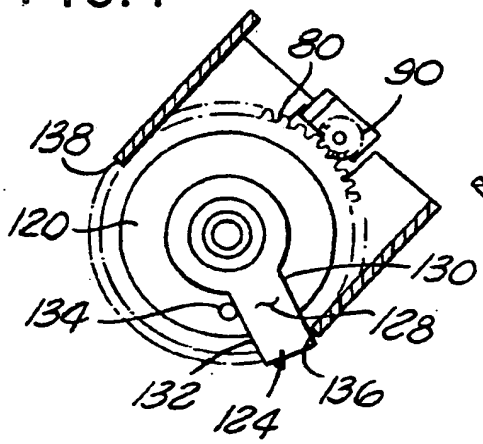


FIG. 7



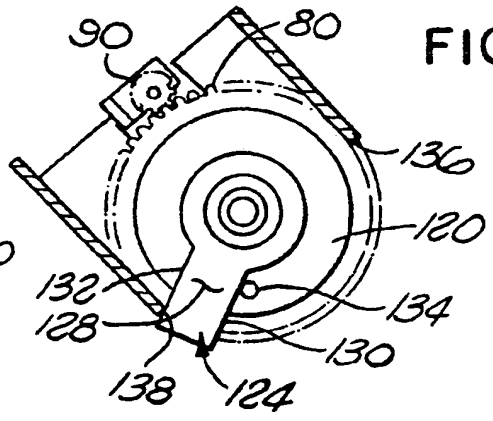


FIG. 8

SPECIFICATION

Manipulator apparatus

This invention relates generally to manipulator apparatus and, more particularly, to remotely controllable manipulator apparatus which is capable of operations which simulate certain movements of the human body, such as the shoulder, upper arm, forearm and wrist.

Many manipulator devices have been proposed in the past for transmission of desired movements from a control member at one location to a remote location for performing different manufacturing functions at the remote location, transporting material or the like. Attempts have also been made to provide manipulator devices in which the movements of the human body, particularly the shoulder and arm, can be simulated. In such prior devices, movement between adjacent sections of the arm occurs through a pivot mechanism that requires some means for transmitting mechanical motion from one arm section through the mechanism to the other arm section, for example, bevel gears, worm gears, linkage, cables or the like. Such prior arrangements are significantly limited in their flexibility by their inherent structure and are relatively expensive and cumbersome.

It is the object of the present invention to provide manipulator apparatus which provides greater flexibility of movement, which is relatively simple and inexpensive, and permits the addition or subtraction of arm sections without affecting the other sections of the apparatus.

According to a principal aspect of the present invention, there is provided manipulator apparatus comprising a plurality of movable arm sections connected in series by remotely controllable pivoting mechanisms, each pivoting mechanism being self-contained except for means for transmitting electrical or fluid power thereto. By this arrangement, there is no necessity for any mechanical motion-transmitting elements interconnecting the arm sections of the manipulator so that substantial flexibility of movement is possible by simply controlling the electrical or fluid power that is transmitted to the individual pivoting mechanisms.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of one embodiment of manipulator apparatus of the present invention embodying four movable arm sections,

Fig. 2 is a schematic illustration showing the apparatus illustrated in Fig. 1 in a position for performing a function under a support table upon which the manipulator apparatus is mounted,

Fig. 3 is an elevation of a manipulator apparatus according to the invention having arm sections and pivot mechanisms arranged to simulate the human arm, in which the pivot mechanism are identical,

Fig. 4 is an enlarged, vertical section taken through the drive and support member of the elbow pivot mechanism, as taken along line 4-4 of Fig. 3,

Fig. 5 is a section taken along line 5-5 of Fig. 3 showing the mounting of one of the driving gears of the pivot mechanism,

Fig. 5A is a side elevation showing the reverse side of the shoulder-pivoting mechanism illustrated in Fig. 3,

Fig. 6 is a vertical sectional view taken through the support member for the elbow-pivoting mechanism taken along line 6-6 of Fig. 3, and

Figs. 7 and 8 are transverse sections illustrating the stop device for the support member at two locations of travel limit as taken along line 7-7 of Fig. 5.

Reference is first made to Figs. 1 and 2 of the drawings which illustrate schematically one form of the manipulator apparatus of the present invention, generally designated 10. The apparatus comprises a base 12 and a plurality of arm sections 14, 16, 18 and 20 which are connected in series. The base 12 of the apparatus is fixedly mounted on a suitable support 22 while an article 24, such as screwdriver, jaws, welding tool, material handling receptacle, or the like is mounted on the outer arm section 20.

Each arm section of the manipulator apparatus embodies a pivoting mechanism 26. The mechanism 26 may be identical. Each pivoting mechanism is capable of pivoting its respective arm section, such as the arm section 14 illustrated in Fig. 1, about a longitudinal axis 28 and also about a transverse axis 30 which is perpendicular to the longitudinal axis providing, in effect, a universal joint at each mechanism 26. Each pivoting mechanism includes a pair of motors, which may be operated by either electrical or fluid power from a remote location, with the drive shaft of one motor concentric with the longitudinal axis 28 and the drive shaft of the other motor concentric with the transverse axis 30, as will be more fully understood from the description of the preferred embodiment of the invention illustrated in Figs. 3 to 8.

The pivoting mechanism 26 associated with the arm section 14 of the manipulator apparatus 10 is supported by the base 12. The pivoting mechanism associated with the next arm section 16 is connected to the outer end of the arm section 14 by a fixed, i.e. non-rotatable, coupling element or shaft 32. The pivoting mechanisms of the arm sections 18 and 20 are also connected to the preceding arm sections by "fixed" shafts or similar coupling means. Thus, no mechanical motion is transmitted from one arm section to the other in the manipulator of the present invention. Each arm section embodies its own pivoting mechanism 26 which is self-contained to the extent that it is operated only through electrical or fluid (hydraulic or air) power which may be transmitted thereto through flexible lines that do not significantly impede the pivotal movement of the arm sections. Therefore, the manipulator of the present invention is capable of multiple movements even to the extent illustrated in Fig. 2 wherein the base 12 of the manipulator 10 is shown mounted on the top of a support 22 while the article 24 on the outer arm section 20 may perform a function not only underneath the support 22 but also on a work piece 34 mounted on the bottom of the support. It will also be appreciated that by the manipulator apparatus of the invention arm sections may be added to or withdrawn from the apparatus without affecting the other arm sections thereby allowing easy modification of the manipulator

apparatus depending upon the intended use of the apparatus.

Reference is now made to Figs. 3 to 8 of the drawings which illustrate in greater detail the structure of a manipulator apparatus in accordance with the invention, generally designated 40, which contains basically three arm sections, rather than four as illustrated in Figs. 1 and 2. As seen in Fig. 3, the manipulator 40 comprises a base 42 fixedly mounted on a support 44, a shoulder - pivoting mechansim 46 having an upper arm 48 mounted thereon, an elbow pivoting mechanism 50 having a forearm 52 mounted thereon and a wrist pivoting mechanism 54 having an article supporting arm 56 mounted thereon. The pivoting mechanisms 46, 50 and 54 may be identical, and correspond to the pivoting mechanism 26 illustrated in Figs. 1 and 2.

The base 42 includes an upwardly extending hollow portion 60 having a cylindrical bore 62 for receiving a tubular stub shaft 64. The shaft is fixed to the base 42 by a set screw or the like, not shown, in order to prevent relative rotation therebetween. A similar "fixed" stub shaft 64 is provided between the outer end of the arm sections 48 and 52 of the manipulator and the next pivoting mechanism 50 and 54, respectively. The lower end of the shaft 64 associated with the base 42 has access to the interior of the base whereby a cable 66 may pass through the base and the shaft 64 into the shoulder pivoting mechanism 46. Similar cables may pass through the stub shafts 64 associated with the pivoting mechanisms 50 and 54, respectively. The cables may carry electrical conductors for controlling electrical motors in the pivoting mechanisms. Alternatively, if the motors are fluid driven, the cables could be flexible fluid-transmitting conduits.

Each pivoting mechanism includes a generally hollow rectangular support 67 which includes upper and lower plates 68 and 70 which are joined to the tubular shaft 64 by plastic bearings 72 and 74. In this manner, the support member is capable of rotating about a vertical axis as defined by the shaft 64. A hub 76 is mounted upon the shaft 64 and affixed thereto by a set screw 78 as best seen in Fig. 4. A gear 80 is fixedly mounted upon the hub 76.

The support 67 supports a pair of reversible electric motors 82 and 84 which are of the DC type, and each motor is mounted upon a speed reduction transmission 86 and 88, respectively. The motor 82 transmission includes an output pinion gear 90 mounted on an output shaft 92, while the motor 84 rotates an output shaft 94 and pinion 96. The transmission drive shafts upon which the pinions are mounted are supported by outboard brackets 98 and 100 mounted on the support member 67, as best seen in Fig. 6. The motor 82 is so mounted that its output shaft 92 is vertically disposed, maintaining engagement of the pinion gear 90 with the gear 80 at the "rear" of the gear as best seen in Figs. 7 and 8.

The support member 67 also includes a pair of stub shafts 102 and 104 defining the horizontal axis about which the arm section pivots, as best seen in Figs. 3 and 5. The stub shaft 104 is mounted upon the support member side plate 106, and the stub shaft 102 is mounted upon the support member side plate 108.

The stub shaft 104 is of cylindrical configuration and includes an outer bearing surface on which a plastic sleeve bearing 109 is mounted. The bearing rotatably supports a hub member 110 upon which there is fixedly mounted a gear 112 so that the shaft 104 rotatably supports the gear.

Fixed to the insides of the stub shafts 102 and 104 of shoulder pivoting mechanism 46 are the legs 114 and 116, respectively, of a bracket which forms the upper arm 48. The forearm 52 is formed by a like bracket which is connected at its lower end to the elbow-pivoting mechanism 50.

The electric motor 84 is mounted in a horizontal manner whereby the output shaft 94 is horizontally disposed and the pinion gear 96 thereon engages the gear 112 as can best be seen in Fig. 3 in the illustration of the elbow-pivoting mechanism 50. Thus, upon rotation of the pinion gear 96 of the shoulder-pivoting mechanism 46, the gear 112 will be rotated to produce a pivoting movement of the upper arm 48 about the horizontal axis passing through the stub shafts 102 and 104. Rotation of the pinion gear 90 of mechanism 46 by the motor 82 thereof will effect rotation of the support member 67 about the vertical axis passing through the shaft 64 and thus pivotal movement of the upper arm 48 around the axis. Thus, the pivoting mechanism 46 allows for both vertical and horizontal adjustment of the upper arm 48.

Rotation of the support member 67 about the shaft 64 is limited by a stop arrangement located adjacent to a flange 120 inwardly formed on the hub 76. The stop arrangement includes a lever 124 disposed on the shaft 64. The lever includes a radially extending portion 128, Fig. 7, of a rather substantial width defined by lateral edges 130 and 132. A stop pin 134 is mounted in the hub flange 120 extending upwardly therefrom in the path of movement of the lever portion 128. The radial length of the lever portion 128 is sufficient to extend the portion for engagement with the ends 136 and 138 of the support member side plates as shown in Figs. 7 and 8. Thus, as the support member 67 rotates relative to the shaft 64 one of the ends 136 or 138 will engage the lever portion 128 and rotate the lever 124 in the same direction of movement about the shaft as the support is rotating under the influence of the motor 82. Movement of the support member in a clockwise direction is prevented when the relationship shown in Fig. 7 is achieved. In this relationship the support plate end 136 engages edge 130 of the lever portion 128 while the stop pin 134 engages the other. Upon rotating the support member 67 in a counterclockwise direction as viewed in Figs. 7 and 8, the plate end 138 will rotate until it engages the edge 132 of the lever portion 128 engaged by the stop 134, and then proceed to rotate the lever in a counterclockwise direction about the shaft 64. This counterclockwise rotation will continue until the relationship shown in Fig. 8 occurs. In this relationship the end 138 has rotated the lever portion 128 until the side 130 now engages the stop pin 134.

In the above-described stop arrangement, the angular displacement of the plate ends 136 and 138 with respect to the shaft 64 and the width of the lever arm portion 128, is such that approximately 380° of rotation of the support 67 is possible before the

support member is restrained against further rotation about its vertical axis. The 380° rotation prevents the cable 66 passing through the base from being excessively twisted, and the requirement for conductor rings and brushes is eliminated, although a significant degree of travel in a horizontal direction is permitted to accommodate the required movement of the manipulator.

Reference is made to United States Patent No. Re. 29,266 which discloses a remote-controlled light using a single pivoting mechanism which is similar to the pivoting mechanisms utilised in the manipulator apparatus of the present invention. However, the present invention teaches the use of several arm sections, each employing a pivoting mechanism, which are mounted in series to provide a highly flexible manipulator apparatus.

It will be noted that the stub shaft 64 which connects the upper portion of the upper arm 48 to the elbow-pivoting mechanism 50 is fixedly connected to both the upper arm bracket and the gear 80 of the elbow-pivoting mechanism so as to provide a non-rotatable interconnection between the upper arm- and forearm-pivoting mechanism. The only power-transmitting element extending from the upper arm 48 to the forearm 52 is the cable 66 through which pass the electrical conductors for controlling the motors in the elbow-pivoting mechanism. Thus, no mechanical motion, such as mechanical torque, is transmitted between the various pivoting mechanisms, or the arm sections mounted thereon. The same relationship exists between the forearm 52 and the article-supporting arm 56 carried by the wrist-pivoting mechanism 54. An article such as a tool or receptacle is mounted on the end of the support arm 56 by fasteners 142. The article 42 as illustrated in Fig. 3 is a cup.

A manipulator apparatus as generally illustrated in Fig. 3 has been mounted on the side of a table having a container of water thereon. By appropriately manipulating the various motors of the pivoting mechanisms of the manipulator apparatus, the operator was able to immerse the cup in the container of water, raise the cup out of the container and move the cup to a position below the table where the cup was inverted for dispensing the contents thereof into the container below the table. Thus, it will be appreciated that the manipulator apparatus is capable of making multiple movements of a complex nature in a relatively simple and inexpensive assembly. If desired, the electrical power delivered to the wrist-pivoting mechanism 54 could be conducted thereto through conductor rings and brushes to permit unlimited rotation of the wrist mechanism about the shaft 64 connected to the forearm 52 which would permit even greater flexibility in the use of the manipulator. Further, a telescoping feature could be incorporated in one or more of the arm sections of the manipulator apparatus for extending or retracting the arms. The telescoping action could be provided by means of a hydraulic cylinder drive within an arm section or by a third reversible motor in the associated pivoting mechanism and an appropriate screw arrangement, not shown.

The respective motor pairs of the pivoting mechanisms 46, 50 and 54 of the manipulator apparatus 40 may be controlled by control circuits similar to that disclosed in United States Patent No. Re. 29,266. Moreover, a joy stick control device may be utilised for controlling the respective motors of the pivoting mechanisms such as disclosed in United States Patent No. 3,835,270. It would also be advantageous to provide an electrical controller which could simultaneously control all the motors of the manipulator apparatus so that only a single control stick would need to be actuated by the operator.

CLAIMS

1. A manipulator apparatus comprising a plurality of movable arm sections connected in series by remotely controllable pivoting means, each pivoting means being self-contained except for means for transmitting electrical or fluid power thereto.

2. A manipulator apparatus as claimed in claim 1, wherein each pivoting means is operable without mechanical motion being transmitted thereto by the other pivoting means or by the arm sections.

3. A manipulator apparatus as claimed in claim 1, wherein each pivoting means is operable to pivot a respective movable arm section about a longitudinal axis and an axis transverse to the longitudinal axis.

4. A manipulator apparatus comprising a base, an upper arm section having shoulder-pivoting means at one end thereof supported by the base, a forearm section having elbow-pivoting means at one end thereof connected to the other end of the upper arm section, article-support means having wrist-pivoting means connected to the other end of said forearm section; the shoulder elbow and wrist-pivoting means being operable to pivot the upper arm section, forearm section and support means, respectively, about longitudinal and transverse axes without mechanical motion being transmitted to said pivoting means.

5. A manipulator apparatus comprising a base and a plurality of arm sections connected in series, each arm section embodying pivoting means for pivoting the arm section about a longitudinal axis and an axis transverse to said longitudinal axis, the pivoting means of one of the arm sections being supported by said base, the pivoting means of each other arm section being connected to the next preceding arm section, and the pivoting means of the other arm sections being interconnected to the next preceding arm sections by coupling means through which no mechanical motion is transmitted.

6. A manipulator apparatus as claimed in claim 5, wherein each pivoting means is operated solely by electrical or fluid power.

7. A manipulator apparatus as claimed in claim 5, wherein each pivoting means includes a pair of electrical motors having their drive shafts disposed perpendicular to each other.

8. A manipulator apparatus as claimed in claim 6, wherein the pivoting means of each arm section is operable independently of the other pivoting means and the other arm sections.

9. A manipulator apparatus comprising a base having a free end and a first axis extending through the free end, a first gear connected to the base concentric with said first axis, a support member mounted on the base for rotation about the first axis, a

bracket having first and second ends, pivot means pivotally supporting the bracket at the one end for oscillation about a second axis extending perpendicular to the first axis, a second gear connected to the bracket concentrically disposed about the second axis, first motor drive means mounted on the support member in operative engagement with the first gear, second motor drive means mounted on the support member in operative engagement with the second gear, a stub shaft fixed to the second end of the bracket having a free end and a third axis extending through the free end of the stub shaft, a third gear connected to the stub shaft concentric with the third axis, a second support member mounted on the base for rotation about the third axis, a second bracket having first and second ends, second pivot means pivotally supporting the second bracket at the one end thereof for oscillation about a fourth axis extending perpendicular to the third axis, a fourth gear connected to the second bracket concentrically disposed about the fourth axis, second motor drive means mounted on the second support member in operative engagement with the third gear; and second motor drive means mounted on the second support member in operative engagement with the fourth gear.

10. A manipulator apparatus as claimed in claim 9 including means on the second end of the second bracket for supporting an article.

11. Manipulator apparatus substantially as described with reference to the accompanying drawings.

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